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TECHNICAL MEMORANDUM

TO: Kelly Manheimer/USEPA DATE: April 21, 2011

COPY: Steven M. Morgan, Esq. / Waste Management

FROM: Peter Quinlan, R.G., Daniel Tartakovsky, Ph.D., Donn Marrin, Ph.D., and Jill Weinberger, Ph.D. / Dudek

SUBJECT: Comments on MWH Groundwater Flow and Solute Transport Simulations to Evaluate Potential TCE Migration from the Bradley Landfill and Recycling Center (January 19, 2011), North Hollywood, California

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Dudek has reviewed the report and numerical groundwater model prepared by MWH on behalf of Honeywell. MWH modified the United States Environmental Protection Agency (USEPA) model in an attempt to simulate the effects of the Verdugo Fault on both groundwater flow and TCE transport at the Bradley Landfill. These revisions, which include introduction of the fault and revisions of the hydraulic conductivity arrays, amount to creation of a new model rather than a mere modification of the existing USEPA model. Consequently, a thorough review of the MWH model, its calibration, and its conclusions are warranted. Our review of the model indicates that the MWH model fails to reproduce historically observed water levels in the vicinity of the Hansen Spreading Grounds. This failure invalidates the model's predictions of water flow and TCE migration in the vicinity of the Bradley Landfill.

Summary

Dudek finds that *the MWH model predicts groundwater elevations that are up to 150 feet higher than measured elevations* in wells located on the north side of the fault, between the Bradley Landfill and the Hansen Spreading Grounds. The excessive groundwater elevations predicted by the model in the vicinity of the Hansen Spreading Grounds indicate that the model does not allow sufficient water to migrate through the Verdugo Fault at this location. As a consequence the model diverts excessive amounts of groundwater flow toward the Bradley landfill. Moreover, while the Hansen Spreading Grounds constitute only 0.15% of the approximately 160 square miles of the entire model domain, they account for 15% of all recharge in the model. *The failures and inconsistencies of the MWH flow model call into question its validity and the veracity of its predictions in the vicinity of the Hansen Spreading Grounds, including the Bradley landfill*. This, in turn, undermines MWH's predictions of both the conductance of the fault near Bradley and potential trichloroethene (TCE) migration from the landfill and through the fault.

I. Introduction

The Bradley Landfill is located on the northeast side of the San Fernando Valley, to the north of the Verdugo fault and the west of the Verdugo Hills. The Verdugo Fault is a thrust fault with a northwest / southeast strike and a northeast dip. This fault affects groundwater flow through the area, as evidenced by groundwater elevation drops of over 100 ft. across the fault. Groundwater flow is also affected by the operations of the Hansen Spreading Grounds located approximately three quarters of a mile north of the landfill, on the northeast side of the fault. The 156 acre spreading grounds, operated by the Los Angeles Department of Public Works (LADPW), provide a place for surface water from Hansen Dam and Big Tujunga Dam to recharge groundwater aquifers (LADPW, 2010).

Version B of the USEPA San Fernando Basin Feasibility Study (USEPA SFBFS-B) model incorporated spreading at the Hansen Spreading grounds but did not include the Verdugo Fault. MWH added the Verdugo fault using the Horizontal Flow Barrier package in MODFLOW to represent the fault as a two-dimensional vertical plane with a uniform conductance of $7.5x10^{-4}$/day. MWH estimated the fault conductance through model calibration. The calibration was limited to wells within one-half mile of the landfill (MWH, 2011), excluding wells located north of the Bradley Landfill, close to the Hansen Spreading Grounds. Yet, a rigorous estimation of the direction and mass of groundwater flow across the Verdugo Fault requires model validation based on predicted groundwater elevations at other wells not used in the calibration between the spreading grounds and the landfill.

Dudek examined measured water levels in wells located to the north of the Bradley Landfill, close to the Hansen Spreading grounds, in addition to the wells used by MWH (Figure 1). Comparison of the observed and simulated groundwater elevations in the northern wells indicates that the model greatly overestimates the head north of the Bradley Landfill.

Data for this study were obtained from the USEPA SFV database (CH2M Hill, 2009) and the Los Angeles County Department of Public Works (LADPW, 2010).

II. Observed Groundwater Elevations

Wells 4905A and 4905H are located approximately three quarters of a mile north of the Bradley Landfill, on the northeast and southwest sides of the Verdugo fault respectively (Figure 1). Groundwater elevations in these wells, which have been measured since 1968, show an average head difference across the fault of 120 ft. and a groundwater elevation at well 4905A that is consistently higher than that at well 4905H (Figure 2)..

Dudek used the measured groundwater elevations at wells 4905A, 4905B, and 4915, all on the northwest side of the fault, to determine the direction of groundwater flow on the north side of the Verdugo Fault in the vicinity of the Hansen Spreading Grounds. This analysis was limited to time prior to December 1980, after which the EPA database does not contain observed data for well 4915. Results for May 1978 and March 1980—two time periods, during which spreading was occurring and for which measurements were taken at all three wells—are presented in Figures 3 and 4. In May 1978, the groundwater flow direction was to the south at an azimuth of 183° (Figure 3). In March 1980, a year of higher spreading, the groundwater flow direction was also to the south-southwest at an azimuth of 205° (Figure 4). This flow direction is roughly perpendicular to the strike of the Verdugo Fault, indicating that groundwater crosses the fault to the north of the Bradley landfill.

III. Simulated Groundwater Elevations

Dudek ran the MWH model using input files provided to USEPA by MWH to simulate water levels at wells 4905A and 4905H (Figures 5 and 6). The average groundwater elevation difference between wells 4905A and 4905H predicted by the MWH model was 177 ft. That is 57 ft. higher than the observed average over the same time period. For example, in the spring of 1995 the simulated head at well 4905A north of the fault was 92 feet *higher* than the observed one, while the simulated head in well 4905H south of the fault is 75 feet *lower* than observed. This clearly indicates that the conductance of the fault assigned by the MWH model in this location is too low. The root mean square (RMS) error for well 4905A is 54 ft. During periods of high volume spreading, the MWH model overestimates the head in well 4905A by as much as 150 ft. The model also overestimates the head in well 4905B, another well located on the north side of the fault, by as much as 109 ft., with the RMS error of 49 ft. MWH reports the RMS error for the wells included in their calibration to be 43 ft. Dudek's analysis of water levels at wells 4905A and 4905H as validation of the model calibration shows that *the MWH model is unable to reproduce observed water levels to the north of the Bradley Landfill.*

Just as the MWH model fails to reproduce the observed head difference across the fault, it is also unable to reproduce the observed flow direction. The modeled flow direction for wells 4905A, 4905B, and 4915 in May 1978 was 157° (Figure 3). In March 1980, the modeled flow direction was 154° (Figure 4). The modeled and observed flow directions differ by 26° in May 1978 and 51° in March 1980. As a consequence, the MWH model directs groundwater flow parallel to the Verdugo Fault from the Hansen Spreading Grounds to the Bradley Landfill.

IV. Changes in Fault Conductance Along the Strike of the Fault

MWH first calibrated their model using a fault conductance value of $1x10^{-6}$/day. Comparison with the observed groundwater elevations at wells 4916C and 4916L indicated that the modeled head difference was too high (MWH, 2011). The MWH solution was to increase the conductance of the fault until the simulated head difference matched the observed difference. If the same approach were used to obtain a better match between the simulated and observed heads at wells 4905A and 4905H, MWH would have to increase the fault conductance in the vicinity of the Hansen Spreading Grounds. Dudek increased the uniform fault conductance by an order of magnitude to do just that (Figure 7). The resulting residuals indicate that the RMS error for well 4905A at the spreading grounds improved from 54 ft. to 32 ft. (Table 1). The RMS error for well 4905H improved from 49 ft. to 41 ft. On the other hand, the RMS error for well 4916L at Bradley increased from 32 ft. to 117 ft. Clearly changes in uniform fault conductance do not improve the ability of the model to reproduce observed heads. These results lead to the conclusion that the conductance of the fault varies along its strike.

Variability in conductance along the fault is also suggested by the change in groundwater flow direction along the strike of the fault. To the north of the landfill, during times of spreading at the Hansen Spreading Grounds, the direction of groundwater flow is to the south or to the south- southwest, across the Verdugo Fault. In contrast, the observed flow direction at the Bradley Landfill for March 2008 is 167° (calculated from wells 4915M, 4915A, and 4915F), or sub-parallel to the strike of the fault.

Variability in the hydraulic conductance along the strike of a fault is routinely observed in geologic studies (Caine et al., 1996; Rawling et al., 2001; Heffner and Fairley, 2005). The hydraulic properties of a fault vary based on the geological setting, the host rocks, the state of stress, and the temporal evolution of the fault (Scholz and Anders 1994). Although less than a mile separates the Hansen Spreading

Grounds and the Bradley Landfill, the two sites are located in different depositional environments. The Hansen Spreading Grounds are located at the mouth of the Big Tujunga Wash, which drains an approximately 200 square mile area of the San Gabriel Mountains (Figure 8). It is likely that higher energy of fluvial processes in the vicinity of the Hansen Spreading Grounds resulted in the deposition of well-sorted, coarse sediments. The Bradley landfill, in contrast, is located at the western terminus of the Verdugo Hills with a watershed of approximately 10 square miles. Sediments deposited at Bradley are likely to come from mass wasting and debris flow, rather than fluvial processes, and are likely to be poorly sorted. Well-sorted sediments generally have higher hydraulic conductivity than poorly-sorted sediments.

Uplift of the San Gabriel Mountains since 5,000,000 years ago (Billen and Houseman, 2004) and the uplift of the Verdugo Hills between 1 and 4 million years ago (Meigs et al., 2003) have channeled water through the Big Tujunga Wash and across the Verdugo Fault for thousands, if not more than one million, years. The accumulated years of water flow may have resulted in the transport of fine sediments of fault gouge away from the fault, partially restoring the hydraulic conductivity of the coarse sediments deposited by Big Tujunga Wash. *The differences in depositional environments of the Hansen Spreading Grounds and the Bradley Landfill could account for the observed changes in the hydraulic properties along the strike of the fault*.

V. **Effects of Fault Conductance on the Modeled Distribution of TCE**

The following paragraphs address some of the MWH simulations of TCE migration from the Bradley Landfill. But first, it is important to emphasize that the failure of the flow model to adequately recreate the observed hydraulic head and hydraulic gradients in the vicinity of the Hansen Spreading Grounds and Bradley Landfill means that the model is invalid and cannot be relied upon to produce realistic predictions of TCE migration in the vicinity of the fault, Hansen Spreading grounds and the Bradley Landfill.

The intent of the MWH model was to evaluate “the potential tricholoroethene (TCE) migration from the Bradley Landfill” (MWH, 2011). The modeled TCE concentrations presented by MWH for the Base Case Scenario, however, are not representative of either those measured in wells down-gradient of the Bradley Landfill or those in wells south of the Verdugo Fault. Simulated peak TCE concentrations (around 40 micrograms per liter) at well 4916J area factor of 8 greater than any observed concentrations. Simulated concentrations at the Strathern landfill indicate 10 micrograms per liter in well 4928A, whereas observed concentrations never exceeded 1 microgram per liter. The failure of the MWH model to reproduce concentrations observed in wells located just downgradient of Bradley invalidates the simulated TCE migration beyond these wells.

MWH presents the results of five additional transport simulations and makes conclusions about potential TCE migration from Bradley through the fault and into the greater San Fernando Basin. In the first scenario the conductance of the fault was reduced by an order of magnitude. MWH does not present the hydraulic head distribution corresponding to this scenario. As such, Dudek re-ran this scenario using the MWH input files. Figure 9 shows that the predicted heads at Bradley are approximately 85 ft. higher than the base case and the RMS error increased from 32 ft. to 78 ft. (Table 1). The simulated water levels at well 4916C south of the fault at Bradley decreased approximately 10 ft. (Figure 10). Thus the head difference across the fault increased approximately 95 ft., producing a much steeper gradient across the fault than has been observed. The overestimation of gradient implies overestimation of flow through the fault. The simulated heads at the Hansen Spreading Grounds also increased creating greater differences from the observed data. The RMS error in well 4905A increased from 54 ft. for the base case to 95 ft. for the lowered conductance case. Again, this change forced more water southeast north of the fault toward Bradley. In addition, the TCE plume simulated by the model overestimates the TCE concentration at well V14WBRS1. Measured concentrations of TCE in well V14WBRS1 varied from 0.5 to 2.8 ug/L in 2006 and 2007. The model predicts concentrations between 5 and 10 ug/L. This overestimation may be the direct result of forcing too much water through the Bradley Landfill and the Verdugo Fault.

The TCE plumes generated in MWH's second and third scenarios (Original Horizontal Conductivity and High Distribution Coefficient) overestimates the observed TCE concentrations at the Newberry and Strathern Landfills, and in well NH-VPB-09. Additionally, the third scenario predicts TCE concentrations in excess of 10 ug/L over a large area situated north and south of the fault. This concentration is higher than any TCE concentrations recently measured in the down-gradient Bradley wells.

No figures were provided to analyze the results of the fourth scenario (Reduced Source Concentration). The best temporal and spatial fit with measured TCE concentrations was achieved in scenario five (Limited Release), in which the TCE source area and release period are both limited. However, even in this case, the simulated concentrations of TCE in well 4916J are a factor of six greater than observed.

The MWH model is unable to reproduce the observed concentrations in well 4916C using sources at the Bradley Landfill under any of the simulated scenarios. MWH's hypothesis that there is a TCE source located hydraulically up-gradient of well 4916C is consistent with both the inorganic chemistry and TCE/PCE ratios detected in this well compared to those detected in the down-gradient wells at Bradley. However, the low hydraulic conductivity of the fault suggests that TCE migrates from an up-gradient source to well 4916C in groundwater that flows along the south side of the fault and does not originate from the Bradley Landfill.

VI. **Conclusions**

The MWH model predictions of groundwater levels are as much as 150 feet higher than those observed in the vicinity of the Hansen Spreading Grounds. This indicates that the MWH model does not allow sufficient water to migrate through the Verdugo Fault at this location. As a consequence, the model diverts excessive amounts of groundwater flow toward the Bradley landfill. The failure of the MWH model to adequately reproduce the potentiometric impact of this major recharge source calls into question the validity of the model and any predictive simulations performed using it in the vicinity of the Hansen Spreading Grounds, including the Bradley landfill. The inadequacy of the flow model in turn calls into question MWH's conclusions regarding the conductance of the fault near Bradley and the simulated potential TCE migration from the landfill and through the fault.

The plumes of TCE generated by the MWH model result from the increased groundwater flow through the Bradley Landfill and the Verdugo Fault in the vicinity of Bradley. These simulations fail to reproduce the concentrations of TCE measured in monitoring wells down-gradient of the landfill, both north and south of the Verdugo Fault.

The MWH model fails to reproduce the observed concentrations in well 4916C using sources at the Bradley Landfill under any of the simulated scenarios. MWH's hypothesis that there is a TCE source located hydraulically up-gradient of well 4916C is consistent with both the inorganic chemistry and TCE/PCE ratios detected in this well compared to those detected in the down-gradient wells at Bradley.

In order to model transport of TCE from the Bradley Landfill, MWH must first simulate the observed hydraulic gradient to the north of and across the Bradley Landfill. This will likely require changing the conductance of the fault from north to south. Until the model reproduces the observed hydraulic gradient, the current MWH conclusions about TCE transport are speculative at best.

VII. **References**

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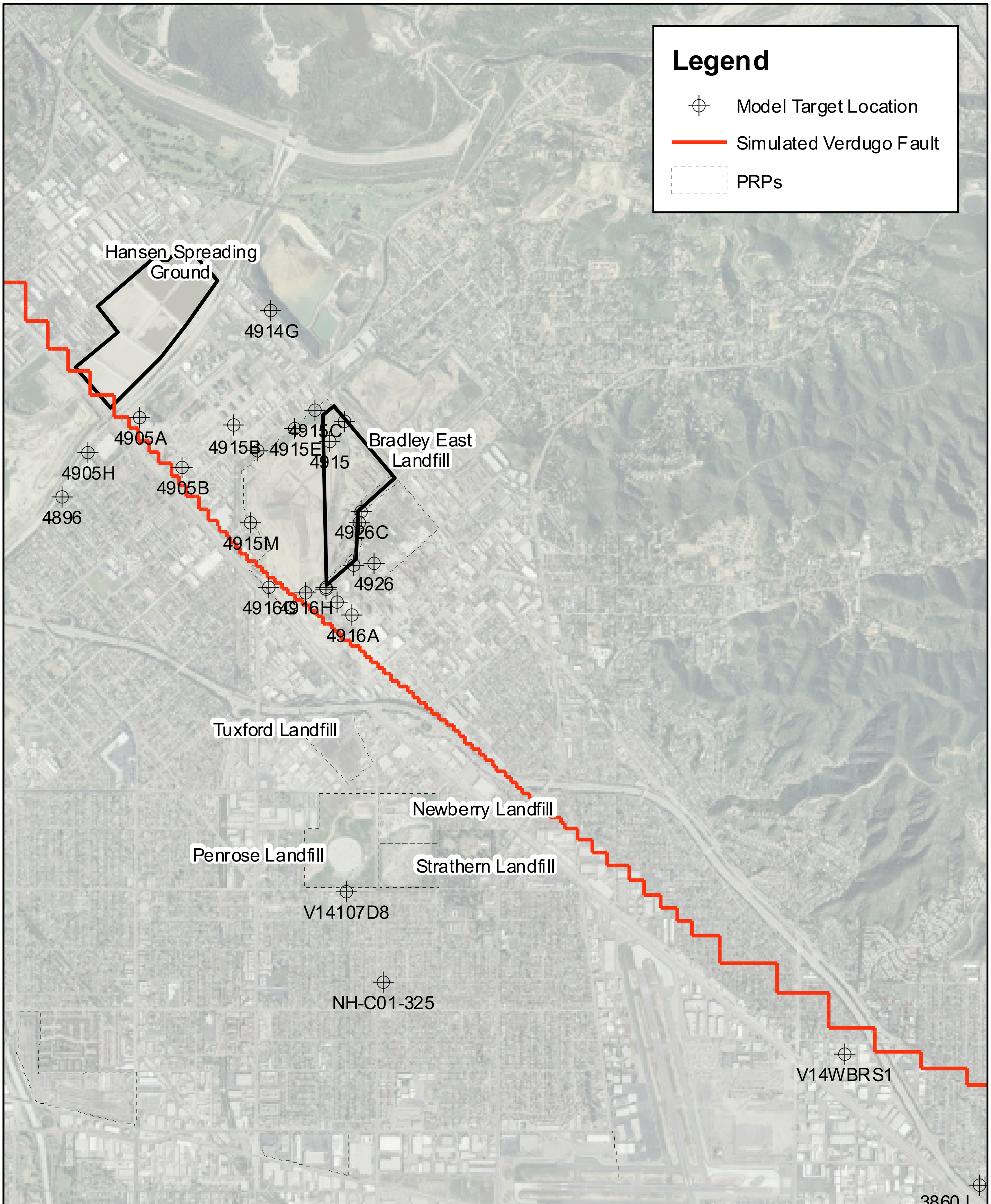

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0 500 1,000 2,000 3,000 Feet

NORTH HOLLYWOOD

SOURCE: Aerial Photo ESRI World Imagry

FIGURE 1

Vicinity Map

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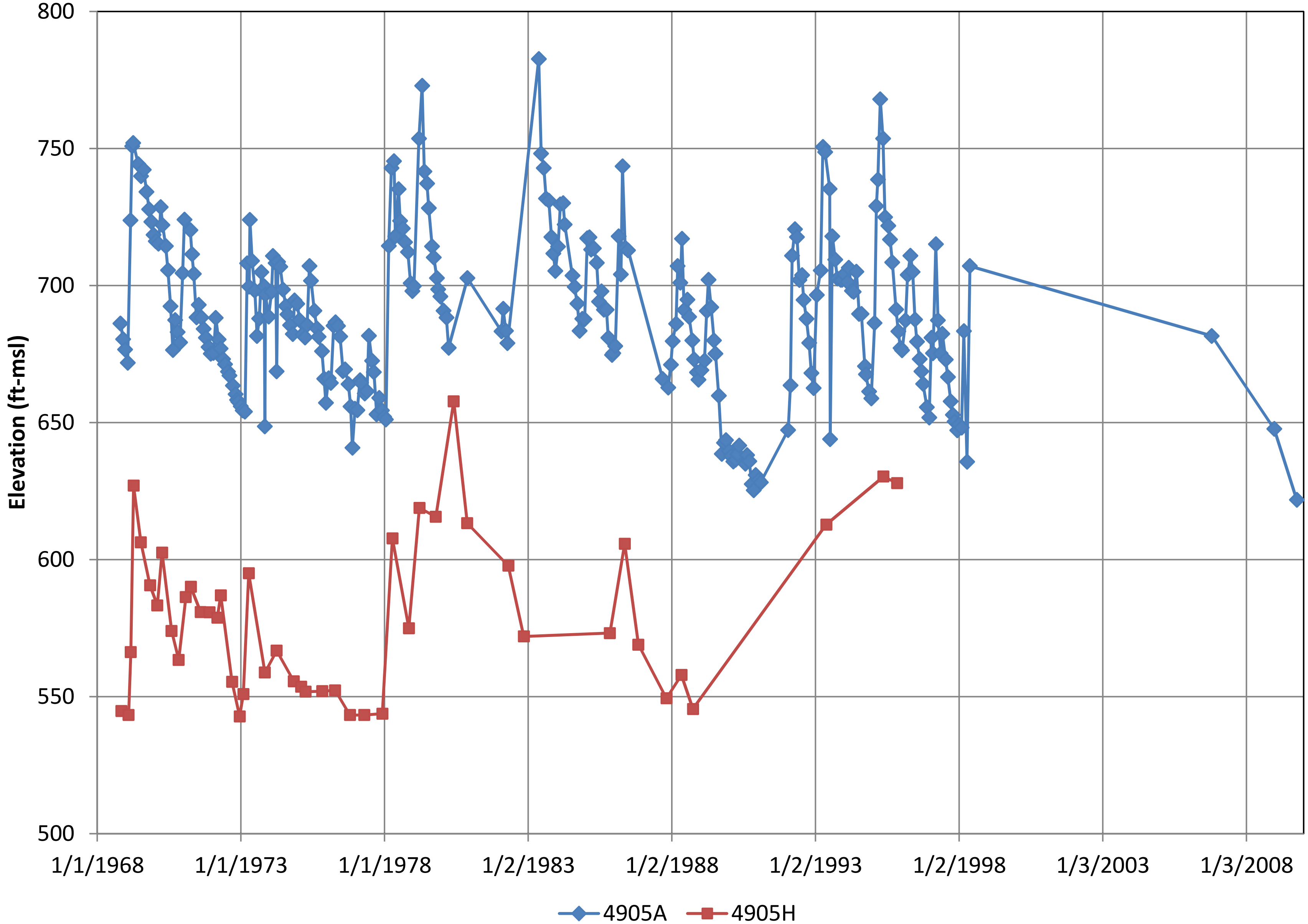
Figure 2. Observed Groundwater Elevations at Wells 4905A and 4905H



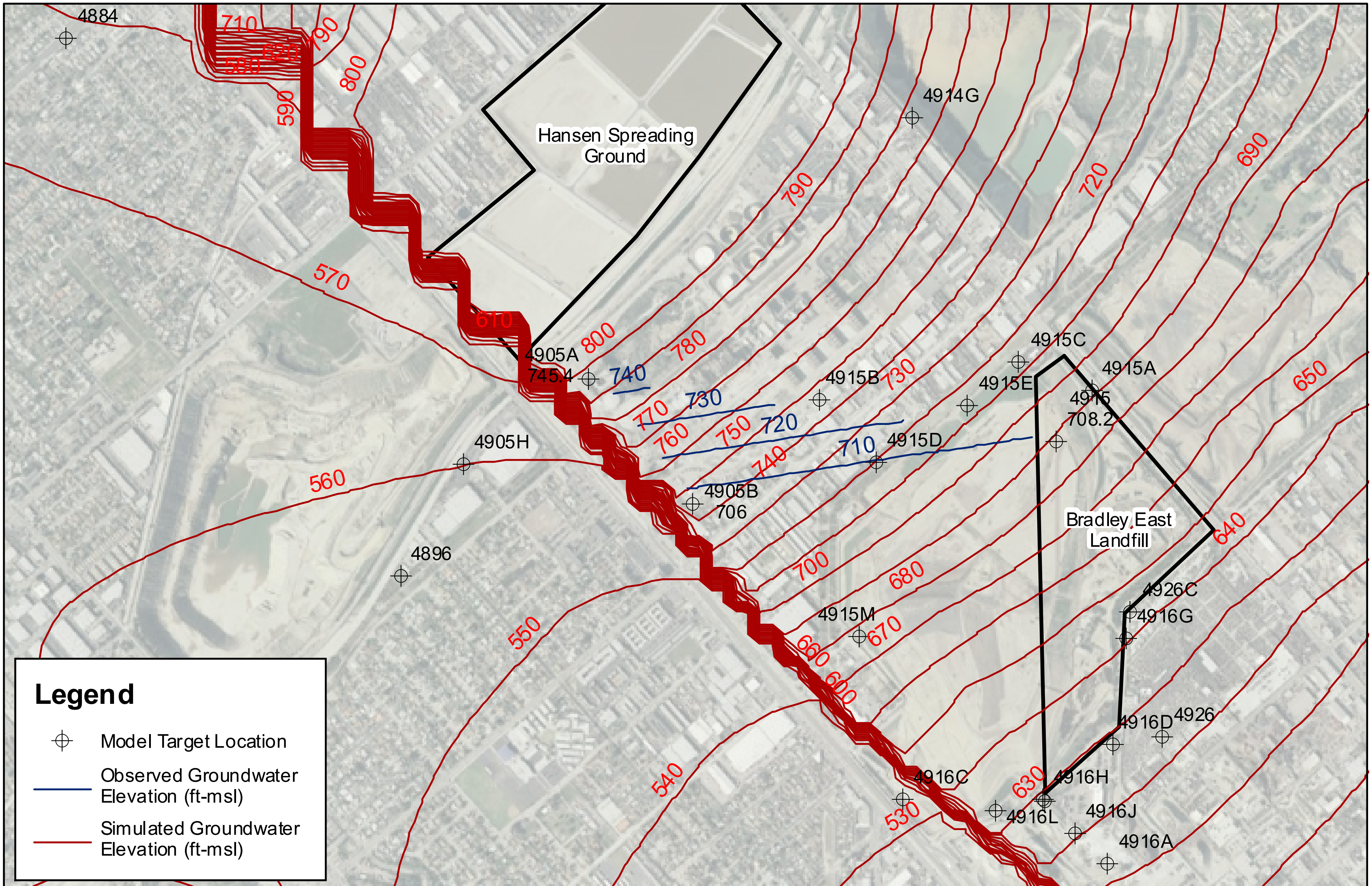


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FIGURE 3

Simulated Versus Observed Groundwater Elevations, May 1978

NORTH HOLLYWOOD

SOURCE: Aerial Photo ESRI World Imagry

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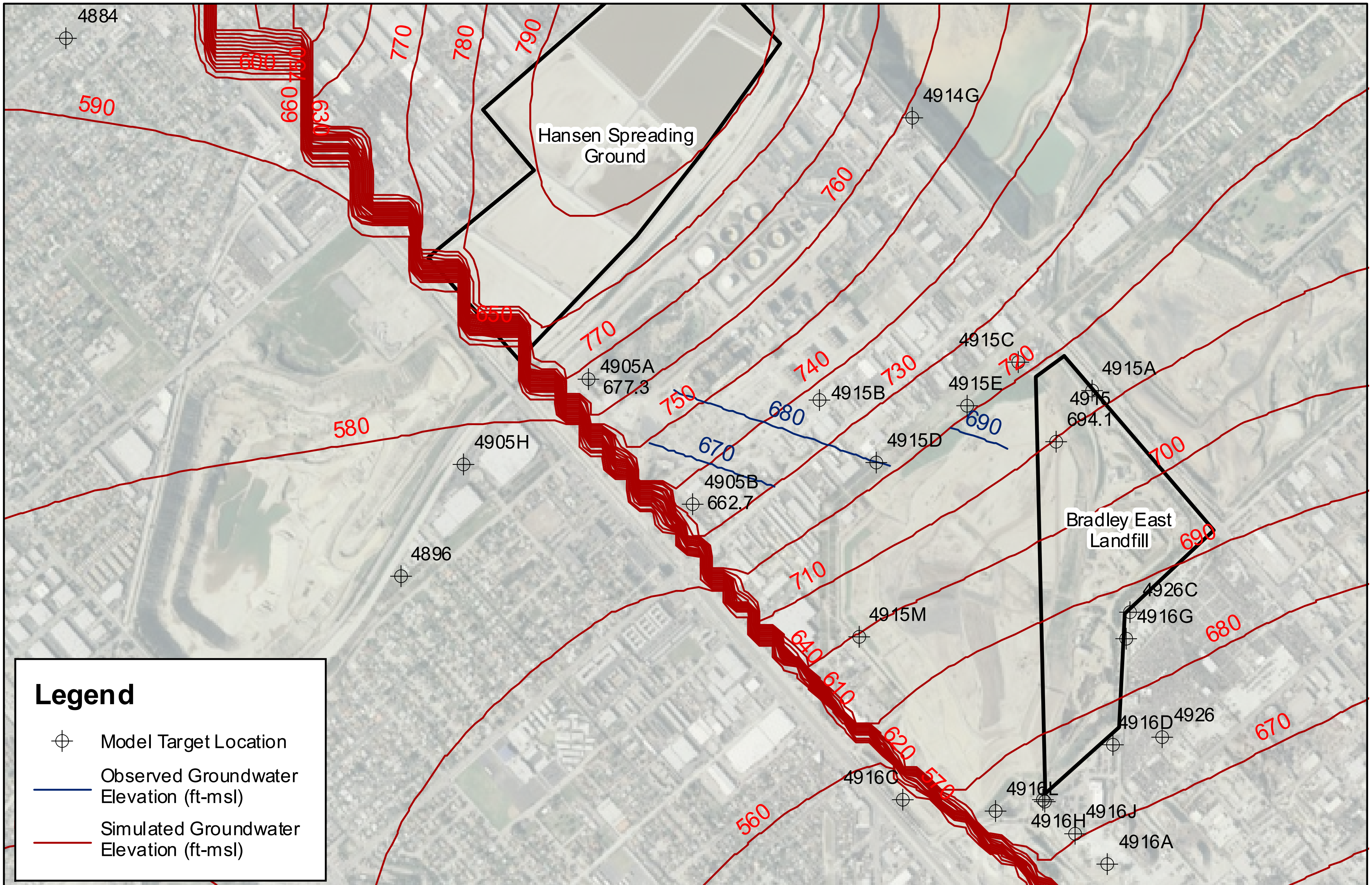

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FIGURE 4

Simulated Versus Observed Groundwater Elevations, March 1980

NORTH HOLLYWOOD

SOURCE: Aerial Photo ESRI World Imagry

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Figure 5: Simulated Versus Observed Head for Groundwater Well 4905A

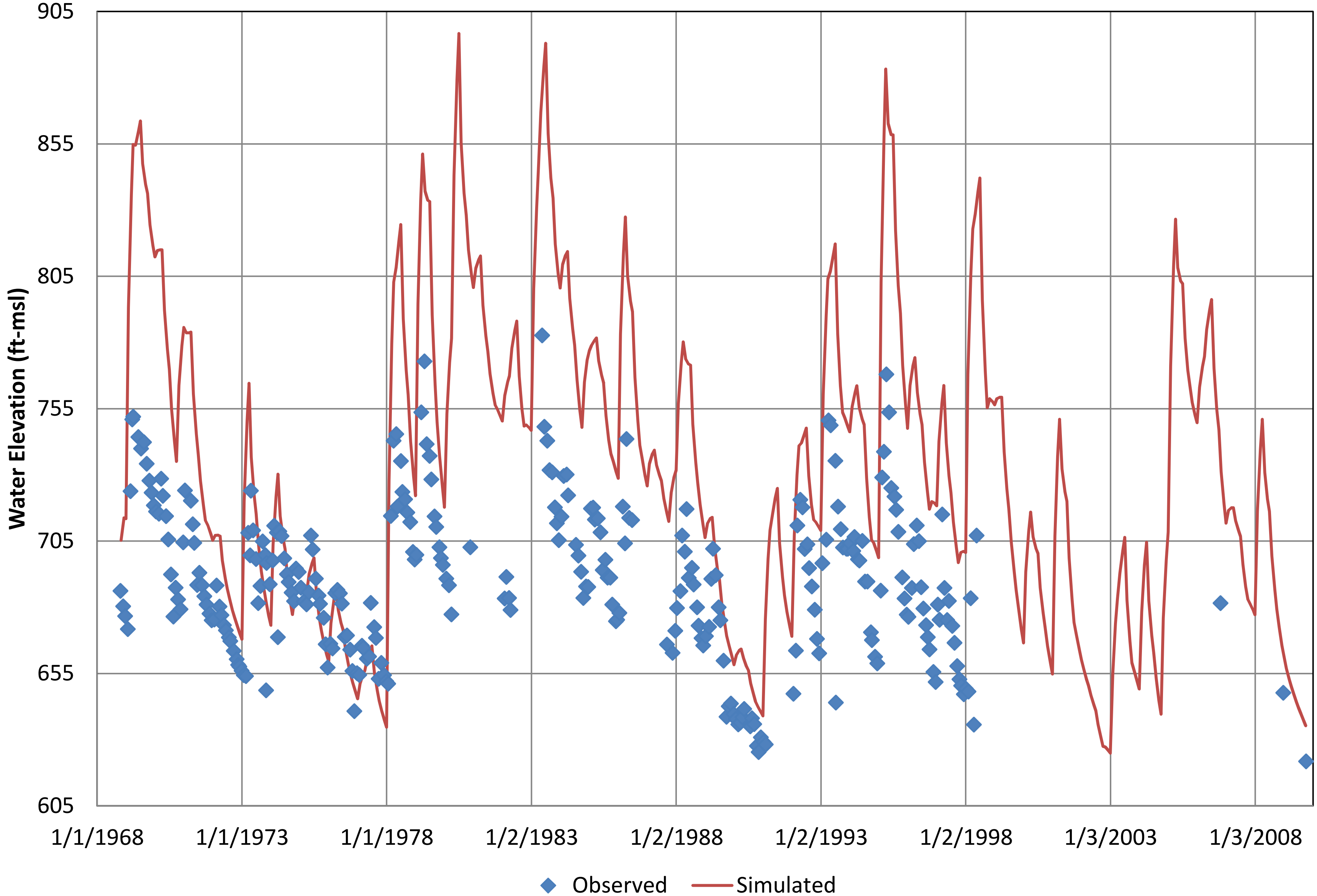


Figure 6: Simulated Versus Observed Head for Groundwater Well 4905H

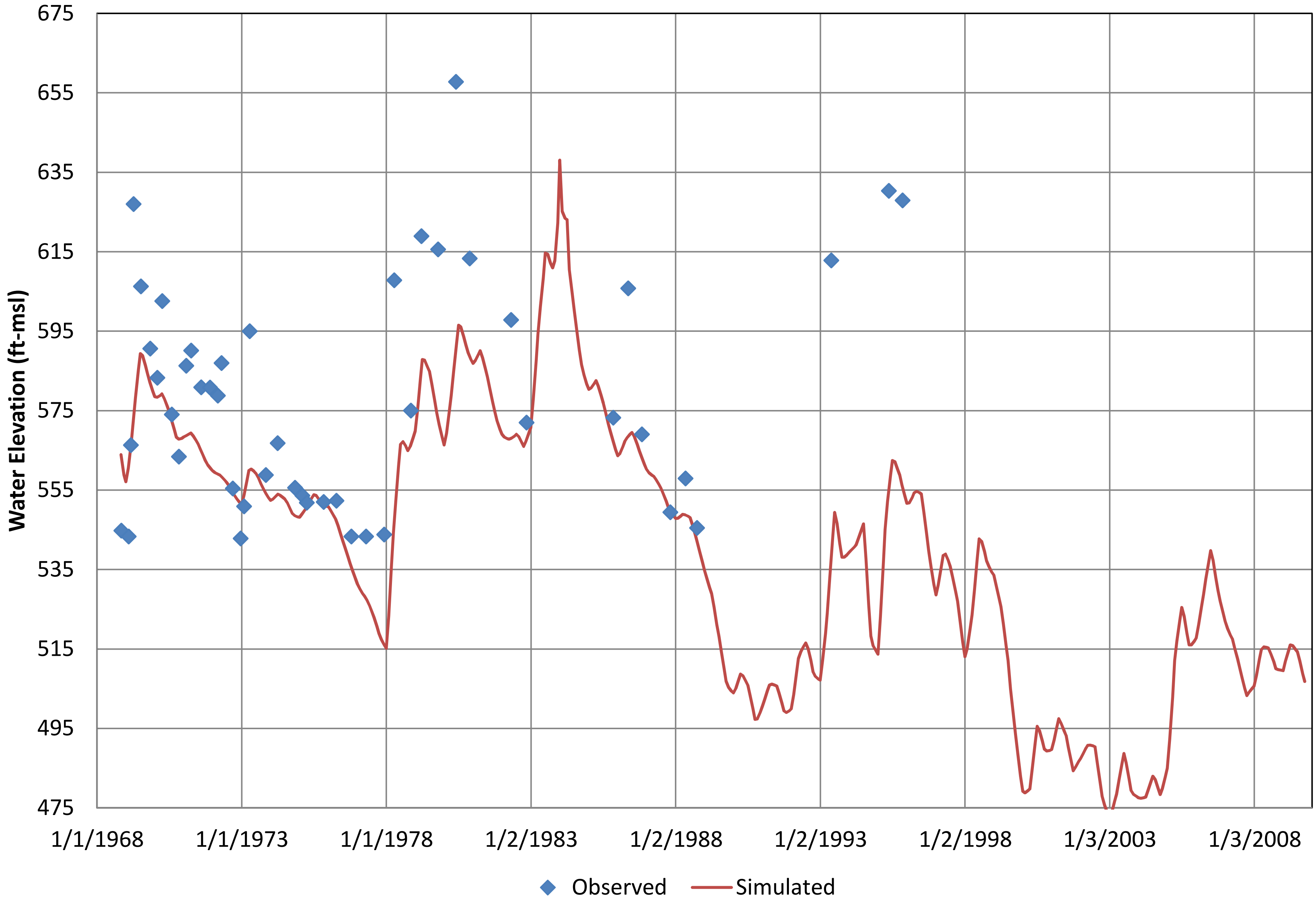
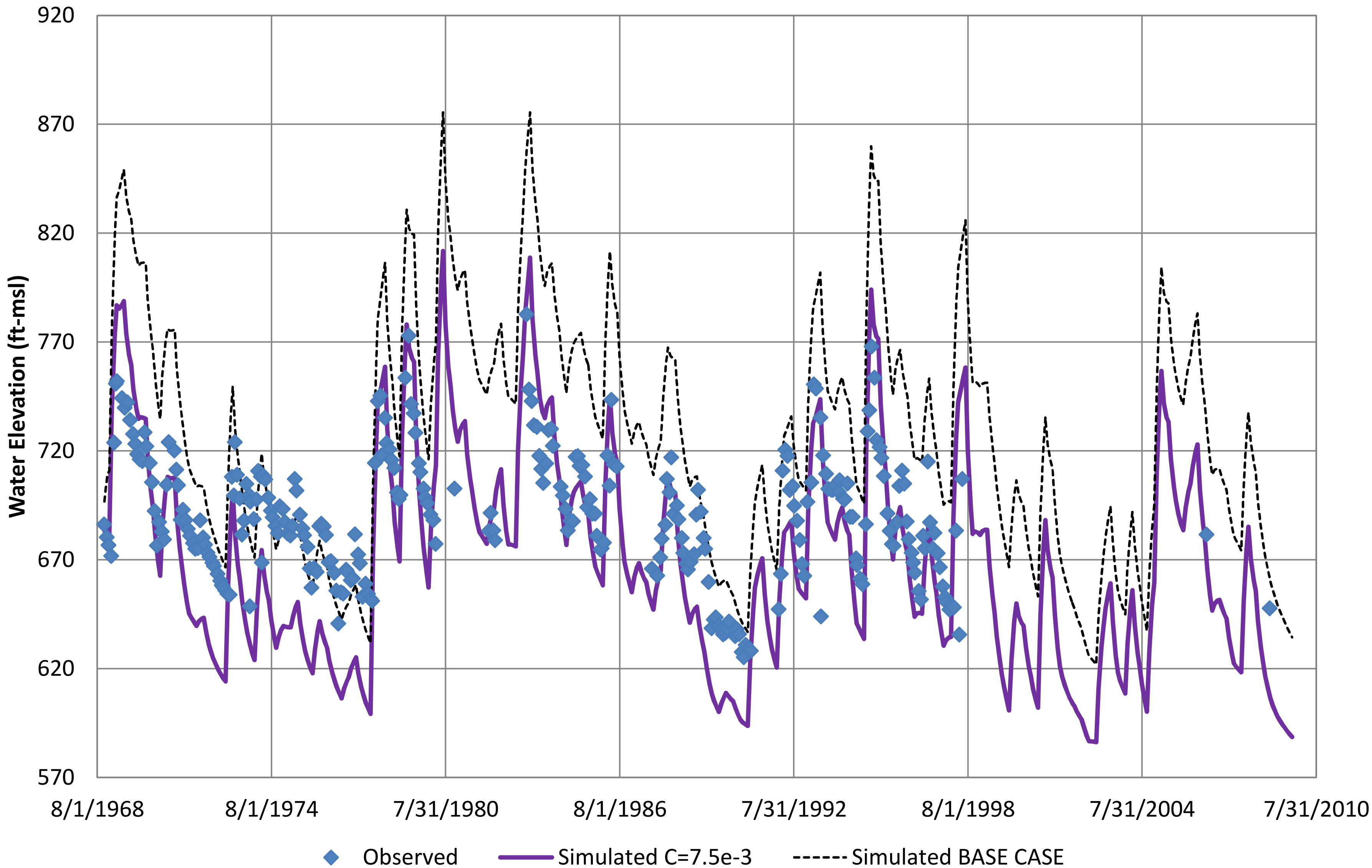
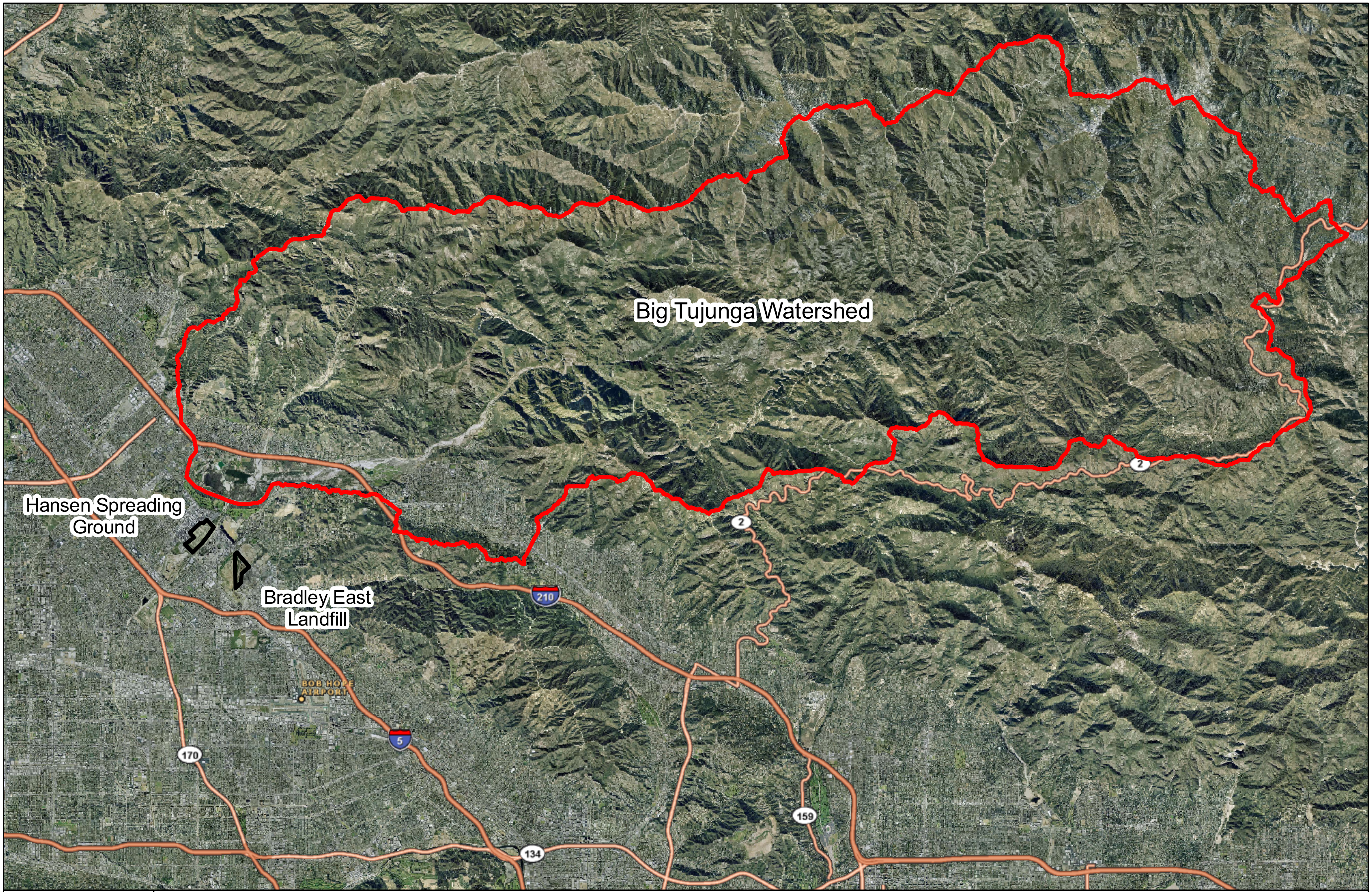


Figure 7. Simulated Versus Observed Head for Groundwater Well 4905A
Fault Conductance Sensitivity Analysis





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0 2.5 5 Miles

NORTH HOLLYWOOD

SOURCE: Aerial Photo ESRI World Imagry

FIGURE 8

Big Tujunga Watershed

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Figure 9. Simulated Versus Observed Head for Groundwater Well 4916L
Fault Conductance Sensitivity Analysis

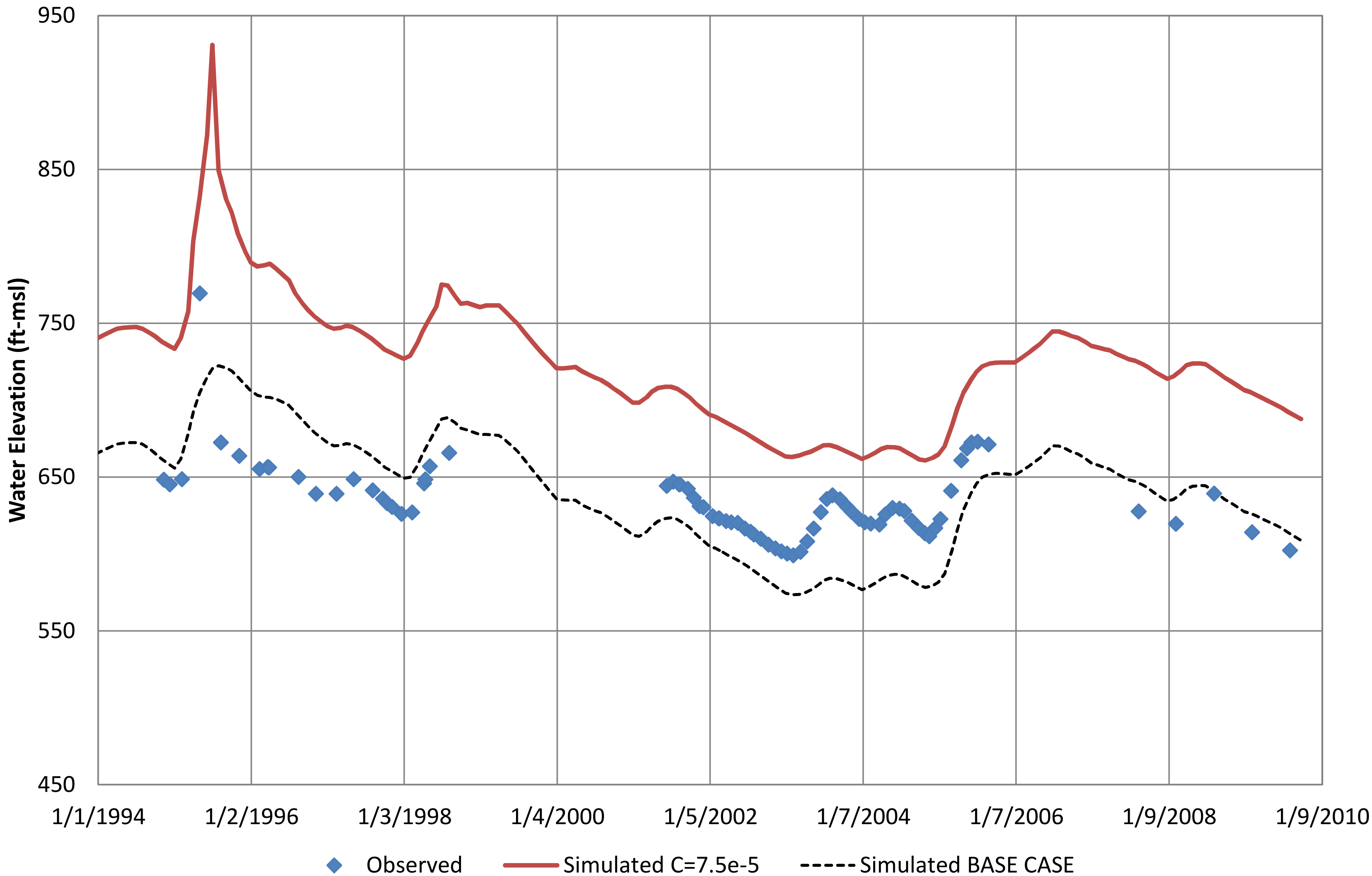

Figure 10. Simulated Versus Observed Head for Groundwater Well 4916C
Fault Conductance Sensitivity Analysis

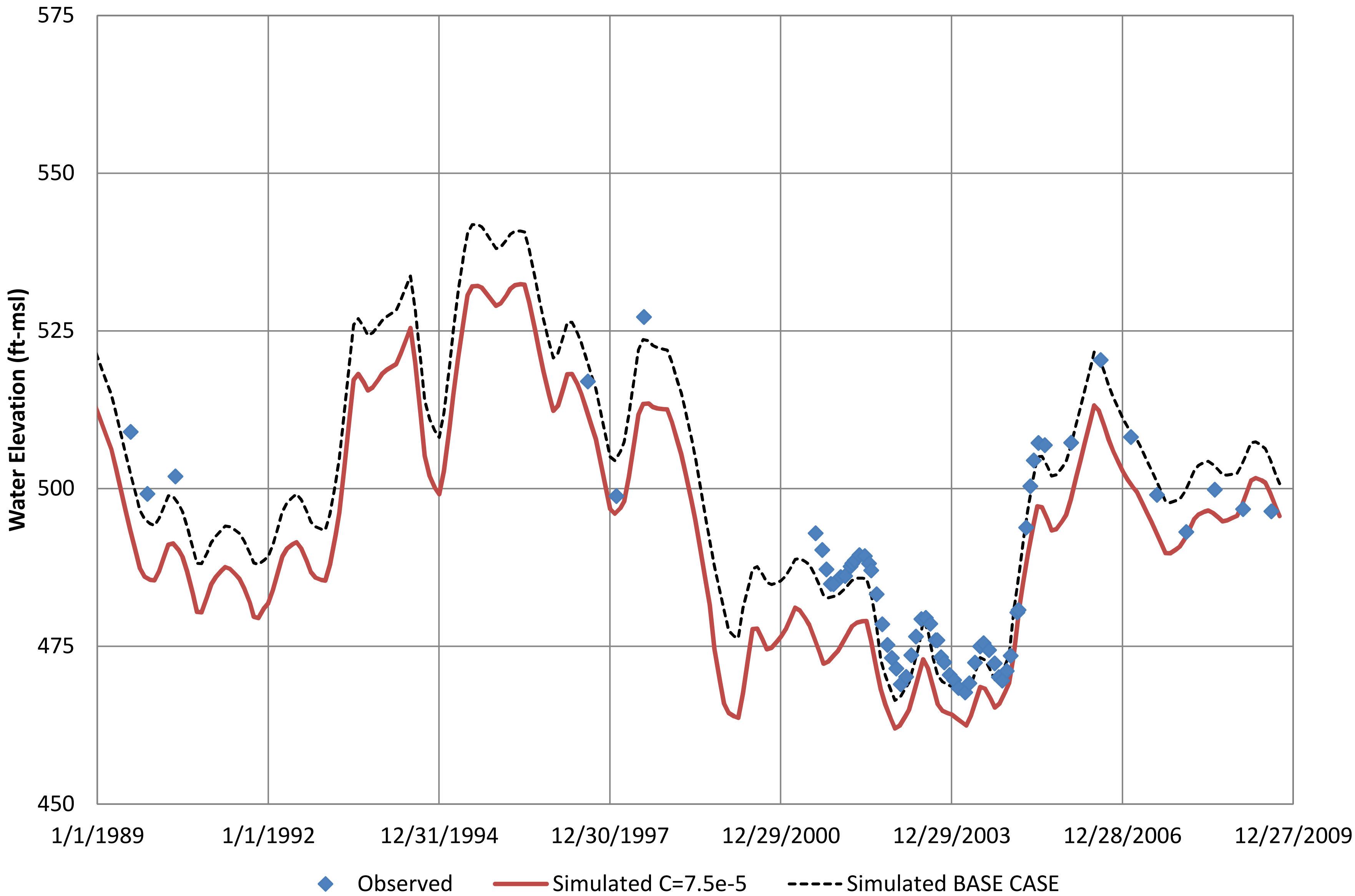

Table 1. Root Mean Squared Error

	Fault Conductance		
	7.50E-04	7.50E-03	7.50E-05
Well	(Base Case)	(10X Higher)	(10X Lower)
4905A	54.22	31.93	95.48
4905B	48.53	40.52	97.39
4905H	29.36	21.75	32.98
4916C	3.72	5.37	8.96
4916L	32.39	117.12	76.53
4915	30.01	67.6	58.07
Model	31.25	61.47	78.02